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A CONSIDERATION ON COMMON PATH LENGTH AND SINGLE STAIRWAY

Study on the Safety Performance of Exit Provisions Part 2

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ABSTRACT

Usually, it is required by building codes that two or more escape routes be available from every point in a building for the purpose of assuring at least one available egress route should the other happen to be blocked by fire. The limitation of common path length and the requirement of two or more stairways for buildings exceeding certain size are typical examples of such requirements. Despite of their vital influence on building design, lucid explanation has not been given to the adequacy of the provisions. In this paper, the meaning of the code requirements on common path length and number of stairway are discussed, and the criterion that may be used as an alternative to such prescribed standards is derived based on the consideration of the expected number of occupants unable to escape.

1. INTRODUCTION

It is commonly deemed to be important for safe evacuation in building fire that two or more escape routes are arranged in different directions. Usually, it is required by building codes that two or more escape routes be available from every point in a building. This intends to assure at least one available egress route should the other happen to be blocked by fire.

The limitation of common path length and the requirement of two or more stairways for buildings exceeding certain size are typical examples of such requirements. Purely from the viewpoint of safe escape, it is desirable that the common path is as short as possible, and that two or more stairways are provided for every building. But such ideal plans are not always realized in real buildings because of the constraints of economy and convenience in normal use. However ideal they may be from the fire safety point of view, it is difficult to oblige to sacrifice everyday benefits excessively since fires are no longer so frequent threats in developed countries.

In building codes, a certain length of common path and single stairway are accepted under some conditions as a result of compromise between the safety and the building economy in broad sense. Still, building plans are significantly affected by such requirements. Despite of the vital influence on building design, lucid explanation has not been given to the adequacy of the provisions.

In this paper, the meaning of the code requirements on common path length and number of stairway are discussed, and the criterion that may be used as an alternative to such prescribed standards is derived based on the consideration of the expected number of occupants unable to escape.

2. PROVISIONS OF COMMON PATH LENGTH IN THE EXISTING REGULATIONS

2.1 Provisions for the Arrangement of Exits

The provisions for the arrangement of escape routes in the existing codes dealing with fire safety include maximum travel distance to stairway, minimum distance between exits or stairway, maximum length of dead end corridor etc. as well as the limitation of common path length.

The provisions on maximum travel distance and common path length in several countries are compared in Table 1¹. The values of maximum travel distance in the countries differ significantly depending on various features of buildings such as occupancy, number of stories, sprinkler installation and so forth. Common path length is likely to be determined in connection with , at roughly one half of, the maximum travel distance.

2.2 Maximum Travel Distance

Maximum travel distance is the limit of distance to cover from a point on a floor to an exit to outdoor or a protected escape path such as a smokeproof tower. There are two ways of measurement for the maximum travel distance depending on code, that is, one which measure from the remotest point including the interior of a room and the other which measure from the doorway of a room.

TABLE 1 Arrangement of Means of Escape

	Australia	France	Japan	U.K.	U.S.
Maximum Travel Distance	a) Apartment, Hotel N.R. b) Assembly 60 m in room 40 m door-exit 20 m c) Hospital(ward) 30 m d) others 40 m	a) General 40 m b) from unprotected stairs 30 m c) from dead-end 30 m d) Hotel door-exit 40 m e) Apartment smoke controlled door-exit 15 m open-air corridor door-exit N.R.	a) Shop, Office =<14th stories 30m =>15th stories 20m b) others =<14th stories 50m =>15th stories 40m * interior finished with non-combustible material +10 m	number of direction <1>/<2> a) Assembly, School 15 m/ 32 m b) Hospital 9 m/ 18 m c) Hotel bedroom 9m/18m elsewhere 18m/35m d) Apartment in room 9 m unit door-exit 7.5 m/ 30 m e) Shop, Office 18 m/ 45 m	a) Assembly 45m (60m) b) School 45m (60m) c) Hospital (60m) in room 23m (38m) door- 30m (60m) d) Hotel, Apartment in room 23m (38m) door- 30m (60m) e) Shop 30m (60m) f) Office 60m (91m)
Common Path of Travel	a) Apartment, Hotel door-exit 6 m others 20 m b) Hospital(ward) 12 m c) Shop, Office 30 m d) single stairs 30 m e) others 20 m	from door at dead-end 10 m	1/2 of maximum travel distance		a) Assembly 6.1m (6.1m) area =< 50 Ps. 23m (23m) b) School 23m (23m) c) Hospital N.R. d) Hotel, Apartment except in room 10.7m (15m) e) Shop 23m (30m) f) Office 23m (30m) one tenant =< 30Ps. 30m

Ps.: persons, () : sprinklered

The meaning of maximum travel distance in the context of escape in fire is interpreted as either of the followings:

- (1) The limit of the distance which evacuees can manage to reach a stair running through a smoke clogged space such as a corridor etc.
- (2) The limit of the distance which evacuees can manage to reach a stair before the escape routes such as a corridor has been smoke clogged.

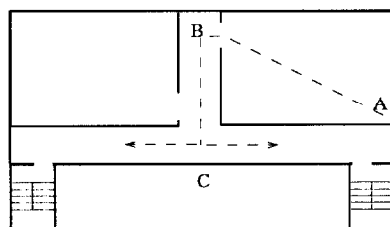
In any case, the essential meaning of the maximum travel distance is nothing but the limitation of travel time to a protected stair in view of safety from smoke. In this sense, it may be allowed to relax the limitation of maximum travel distance if the danger by smoke is considered to be low. In fact, the distance is relaxed according to the degree of fire retardation of interior linings in Japan, and by sprinkler installation in the U.S.A. In France, there is no limitation on the distance for open-air corridors of apartment buildings.

2.3. The Objective of the Limitation of Common Path Length

Common path length is the distance from where egress start to where two or more escape directions are available. Typical concept of common path is illustrated in Figure 1a. Common path length is usually measured from the remotest point in a room, but may be measured from doorway in some cases, such as collective dwellings and lodging facilities.

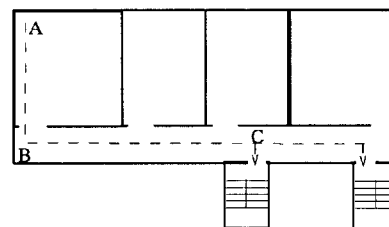
In actual buildings, common path appears in such plans as shown in Figure 1b more frequently than the plan in Figure 1a. In such a case, evacuees only have to cover the distance of the common path length to reach a stair as long as they do not fail to find the stair, so practically the limitation of common path length induces the reinforcement of maximum travel distance.

The role of the limitation of common path length is different from that of maximum travel distance: The basic concept of common path length is shown by Figure 1a. Obviously, it is not enough to cover the common path to get to a safe place such as a stair case. It is not common path length but maximum travel distance that has to be limited if the objective is to avoid or mitigate hazards due to smoke.



a. Typical concept

AC: common path of travel



b. Actual arrangement

common path length = maximum travel distance

BC: common path of travel in corridors

FIGURE 1 Examples of Common Path of Travel

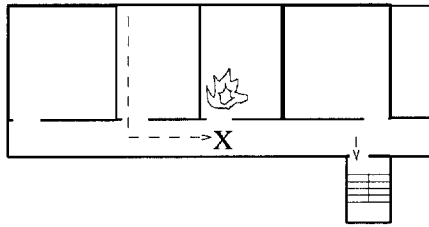


FIGURE 2 A fire blocks only one escape route to a stairway

The objective of the limitation of common path length is considered to reduce the risk that escape is blocked by the fire which happens to occur on the egress path to a stair or other places of final safety. The typical scenario will be, as shown in Figure 2, that a fire breaks out in a room along one way corridor and the flames or hot gases ejecting out from the doorway impedes the passage of the occupants in the rooms located at the opposite side of a stairway. The meaning of the limitation of common path length is to limit the number of the occupants who may lose the only escape means.

3. CONDITIONS ALLOWED IN CASE OF SINGLE STAIRWAY

In principle, building codes require two or more stairways as the vertical escape routes in multiple story buildings. However, it is allowed to have only one stairways under certain conditions since it is not practical to require two or more stairways to all buildings. Table 2 summarizes the conditions associated with the relaxation of the requirements of two or more exits¹.

From Table 2, it can be recognized that basically three main factors are involved when a single stairway is accepted, i.e., number of occupants on a floor, number of floors and characteristic of occupants, but other different factors are also taken into account in different codes. In average, the maximum number of occupants are limited to 50, but the number is limited to a smaller value for buildings of residential or medical care uses. With this restriction, goes the limitation of number of floors, or building height, which differs somewhat in different codes. This limitation is considered

TABLE 2 Condition allowed in case of single stairway

	Australia	France	Japan	U.K.	U.S.
Single Stairs	a) =<6 stories or =<25 m height <u>Hospital, Assembly, School</u> b) =<6 stories or =<25 m height & any story >50 Ps. except * ward floor * preschool * primary or secondary school	for story or part of story 1) =<19Ps. 1 2) =<50 Ps. 1+sub <u>Apartment</u> a) combinations of stairs and corridors opened to the air or with smoke control b) stairs with smoke control	=<5th floor & a) on 3–5th floor & S =<200 m ² c) on 2nd floor & S =<400 m ² d) ward floor & S =<100 m ² e) Hotel : floor with sleeping rooms & S =<200 m ² f) Apartment & S =<200 m ² except * Assembly, * Shop	<u>Apartment</u> a) top floor <11m, =<4 stories, travel to exit <4.5 m <u>others</u> c) top floor <11m, =<50 Ps. d) room =< 50 Ps. e) story =<50 Ps.	<u>Assembly</u> a) balcony<50 Ps. <u>Hotel, Apartment</u> b) =< 4 stories, =<4 living units per story, sprinkled <u>Office</u> c)room/area<100Ps. travel to outside<30m d)=<3 stories, each story < 30Ps., travel to outside<30m

Ps.: persons, S: room area

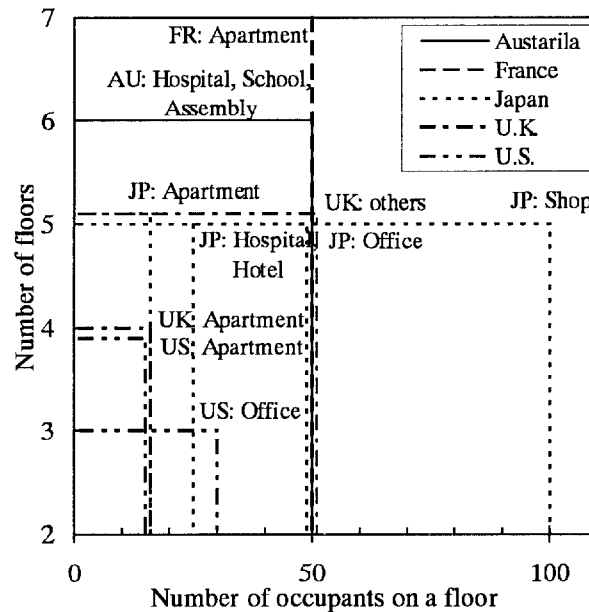


FIGURE 3 Relation between number of occupants on a floor and number of floors for buildings having a single stairway

to be associated with the chance of rescue by fire brigades.

Such concurrent limitations on number of occupants on a floor and number of floors are followed by the limitation of the total number of occupants in a building. Total number of occupants allowed to be accommodated on the second and upper floors in a building ranges from 50 to 400 depending on use of buildings and different codes. The type of buildings in which a large number of occupants are allowed are likely to be those which have no sleeping facility.

4. EXPECTED NUMBER OF OCCUPANTS UNABLE TO ESCAPE ASSOCIATED WITH SINGLE MEANS OF ESCAPE

4.1 Theoretical Consideration

Common path in a corridor and a single stairway have the same issue from the viewpoint of evacuation safety, that is, the occupants are trapped by fire when the fire breaks out in a space on the way to the exit.

(1) Expected number of occupants unable to escape due to common path

The typical plan of the part of buildings to which the limitation of common path applies is shown in Figure 4. Our interest is how the risk on evacuation is related with the common path length. Let n be the number of the rooms along the corridor having only one escape direction to the stairway. The escape from a room is impeded when a fire breaks out between the room and the stair, grows to a hazardous fire and ejects flames or hot gases to the corridor through open doorway. Probability of such an event to occur for an arbitrary room k , which we call here "Escape route obstruction

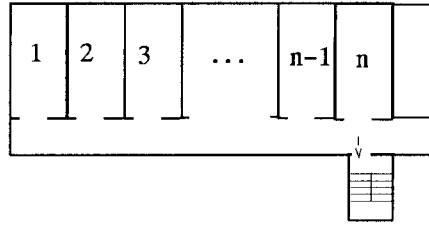


FIGURE 4 n rooms along a corridor having only one escape route to a stairway

probability" can be given as

$$P(k) = p1(k) \cdot p2(k) \cdot p3(k) \quad (1)$$

where $p1(k)$: probability of fire occurrence in the room
 $p2(k)$: probability that the fire grows to a hazardous fire
 $p3(k)$: probability that the door is left open in fire

Next, letting $Q(i)$ be the number of occupants in room i , the expected number of occupants who are unable to escape to the stair e for each potential room of origin k is calculated as

$$\begin{aligned} e(k) &= \{Q(1) + Q(2) + \dots + Q(k-1)\} P(k) \\ &= \left\{ \sum_{i=1}^{k-1} Q(i) \right\} P(k) \end{aligned} \quad (2)$$

respectively.

Hence, the total expected number E which takes into account the possibility of fire occurrence in every room is given as

$$E = \sum_{k=1}^n \left\{ \sum_{i=1}^{k-1} Q(i) \right\} P(k) \quad (3)$$

At the stage of planning of a building, it will be likely that the conditions of such rooms as above is practically regarded as uniform, that is, $P(k)=P$ and $Q(i)=Q$ in Eqn.(2), then the total expected number E is calculated simply as

$$E = \frac{n(n-1)}{2} PQ \quad (4)$$

The value of n is only dependent on the specific plan, and Q may be evaluated from the use and the area of the room. It would be desirable that the probability P be obtained based on fire statistics, but currently not ample statistical data is available for the probabilities included in the right hand side of Eqn.(1), although $p1$ and $p2$ could be roughly estimated. As it is expected to be difficult to determine the absolute value of P , some other way must be sought for handling this factor.

(2) Expected number of occupants unable to escape due to single stairway

Next, let's consider the building consisting of a single stairways and multiple floors as shown in Figure 5. Although the problem in this case may involve some difference from common path, for

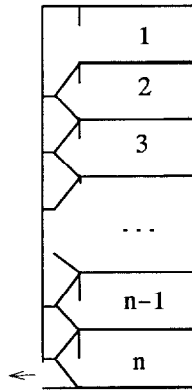


FIGURE 5 n stories high building having a single stairways

instance, the primary threat to evacuation in stairway is more smoke filling than hot gases ejection from door, the issues associated with a single stairway and common path of corridors are considered to be much similar. Hence the same consideration and the equations (1) – (3) may be extended to use for the problem of a single stairway.

4.2 Some Consideration on Effect of Factors

(1) Number of occupants

The provisions of common path length in any country does not explicitly take into account the variables such as n and Q . However, in case of the assemblies and offices in the U.S.A., the limitation of common path length is relaxed when the number of occupants is low. This is considered to be rational because, as can be readily recognized from Eqn.(3), the expected number of occupants unable to escape decreases proportionally to the reduction of the number of occupants.

The expected number E increases drastically with number of rooms n if the number of occupants in a room Q is the same. For instance, E increases by 6 fold if n is doubled from 2 to 4. If the total number of occupants nQ is the same, the expected number E increases proportionally to the number of rooms $n-1$.

(2) Fire suppression system

In the building codes of the U.S. the limitation of common path length is relaxed when the building is sprinklered. This provision may be justified by considering that sprinklers have the effect to reduce the probability that a fire develops to a hazardous level, that is, p_2 in Eqn.(1).

According to the statistics in the U.S. and Canada, the probability of flashover occurrence is reduced to about $1/4 - 1/5$ by the installation of sprinkler system². Because the expected number of occupants should be the same between with and without sprinkler system,

$$\frac{n(n-1)}{2}QP = \frac{n_{sp}(n_{sp}-1)}{2}QP_{sp} \quad (5)$$

that is,

$$\frac{P_{sp}}{P} = \frac{n(n-1)}{n_{sp}(n_{sp}-1)} \approx \frac{1}{4} \quad (6)$$

where n_{sp} : number of rooms in sprinklered condition
 P_{sp} : fire probability in sprinklered condition

For $n > 2$, the value of n_{sp}/n lies between 1.7–2.0. The number of rooms along the corridor forming the common path is considered to be about in proportion to the common path length. Hence, it follows that common path length can be approximately doubled without lowering the safety level of evacuation if the relevant part is sprinklered. In this sense, the U.S. standard for common path length, which relax the length by the equipment of sprinkler system, is thought to be reasonable.

5. CRITERION ALTERNATIVE TO EXISTING STANDARDS ON SINGLE MEANS OF ESCAPE

5.1 Consideration on Some Other Factors

As we have seen in the above, Eqn.(3) can take into account some of the factors which have been incorporated in the existing standards associated with common path length, such as number of occupants, sprinkler system and so forth, by fairly logical manners. But as can be seen in Table 2, some other factors have been taken into account in the existing codes. Hence, we should pay due respect on such factors. They are particularly as follows:

(1) Rescue by fire brigade

Single stairway is basically allowed for relatively low-rise buildings. This implies that the possibly of rescue by fire brigade using fire ladder or some other means of escape are taken into account in case the built-in means of escape, such as stairway and corridor, are made unavailable by fire.

On the other hand, rescue by fire brigade seem to be disregarded in the provisions for common path length in most building codes. The building standards law of Japan is the only code that prescribes different length of common path depending on height of floor, perhaps for some other reason. However, it will be logical that the factor of rescue is considered in common path.

(2) Degree of fire protection of escape route

In France, single stairway is allowed if the stair is protected properly from fire and smoke including being opened to outdoor air. In principle, a single stairway should be sufficient if it is perfectly free from the hazards due to fire. However, perfectly protected stairways are seldom found in real buildings so the level of safety varies depending on the degree of protection. More generally, the degree of protection of staircases and corridors should be added to the assessment by Eqn.(3). In most cases, corridor is closer than stairway to the room of origin, so direct impact of fire is stronger in corridors than in stairway. However, a high degree of protection is conceivable for corridor in some cases. For instance, if a corridor is wide enough, it will be possible to pass in front of the doorway ejecting hot gases from the room of origin.

5.2 Proposed Criterion

Considering the factors mentioned in the above, Eqn.(3) should be slightly modified as

$$E = \left\{ \sum_{k=1}^n \left\{ \sum_{i=1}^{k-1} Q(i) \varphi \right\} P(k) \right\} \delta \quad (7)$$

where φ and δ are the efficiencies of the rescue by fire brigade and degree of protection of escape route on the reduction of occupants unable to escape, respectively.

It is virtually hopeless to obtain the absolute value of $P(k)$, φ and δ , however, if we consider the reference conditions of building space having only one escape route to which maximum number of occupants is allowed by building codes, the critical value of E has to be

$$E \leq Q_{ref} P^* \varphi^* \delta^* \quad (8)$$

where Q_{ref} is the maximum number of occupants, and P^* , φ^* and δ^* are the value of P , φ and δ implicitly assumed for such a space by the codes.

Using Eqns.(7) and (8) yields the expression of the criterion as

$$\left\{ \sum_{k=1}^n \left\{ \sum_{i=1}^{k-1} Q(i) \varphi \right\} \bar{P}(k) \right\} \bar{\delta} \leq Q_{ref} \quad (9)$$

where $P(k)$, φ and δ are relative probability and efficiencies defined as

$$\bar{P}(k) = P(k)/P^*, \quad \bar{\varphi} = \varphi/\varphi^*, \quad \bar{\delta} = \delta/\delta^* \quad (10)$$

5.3 Values of Parameters

From Table 2, it can be recognized that in average sense 50 seems to be the maximum number of occupants allowed for a space without sleeping facilities which has only one escape route, and since no particularly important measure is required on allowing the 50 occupants we may be able to assume such condition that the rescue by fire brigade is not expected nor the escape route is protected. Therefore, for such conditions, let the values of the parameters be as

$$\bar{P}(k)=1, \quad \bar{\varphi}=1, \quad \bar{\delta}=1 \quad \text{and} \quad Q_{ref}=50 \quad (11)$$

(1) Common path in corridor

Next, let's consider on the issue of common path length. Applying Eqn.(9) and (11) to a corridor having only one direction to stairway and n rooms of the same conditions on each side as shown in Figure 4, we have

$$2n(n-1)P_c \bar{\varphi} \bar{\delta} Q \leq 50 \quad (12)$$

where P_c is the relative escape route obstruction probability of corridor.

From Table 1, it is fairly evident that the common path length measured from the doorway of a room to staircase is restricted within 10 m in average. Four single bed rooms may be arranged on each side of the corridor of this length in the business hotel in Japan. Also, considering that the limit of the common path length apply unconditionally, we may be able to let $\varphi=1$ and $\delta=1$. Hence, from Eqn.(12)

$$2 \times 4 \times 3 P_c \bar{\varphi} \bar{\delta} \times 1 = 24 P_c \leq 50$$

that is $P_c = 2$.

Noting that 50 occupants are allowed for the condition without sleeping facilities, applying Eqn.(12) to the same configuration but non sleeping condition yields

$$2 \times 4 \times 3 P_c \bar{\varphi} \bar{\delta} \times \frac{50}{8} = 150 P_c \leq 50$$

that is $P_c = 1/3$.

In summary, the relative escape route obstruction probability of corridor turns out to be

$$P_c = \begin{cases} 2 & \text{(for sleeping use)} \\ 1/3 & \text{(for non-sleeping use)} \end{cases} \quad (13)$$

(2) Single stairway

Now, let's apply Eqn.(9) and (11) to a building having n floors and only one stairway, then we have

$$\frac{n(n-1)}{2} P_s \bar{\varphi} \bar{\delta} Q \leq 50 \quad (14)$$

where P_s is the relative escape route obstruction probability of stairway.

From Table 2, it can be recognized that single stairway is allowed for buildings having four or less floors and four or less dwelling units on each floor. Because the number of floor is four or less it is considered the rescue by fire brigade is normally taken in to account, but a high level of stairway protection is not required. Average number of occupants in a dwelling unit may be estimated as four. Hence, substituting $n=4$, $\delta=1$ and $Q=4$ into Eqn.(14), we have

$$\frac{4 \times 3}{2} P_s \bar{\varphi} \bar{\delta} \times 16 = 96 P_s \bar{\varphi} \leq 50 \quad (15)$$

that is, $P_s \bar{\varphi} = 1/2$.

Noting that 50 occupants are allowed for the condition without sleeping facilities, applying Eqn.(14) to the same configuration but non sleeping condition yields

$$\frac{4 \times 3}{2} P_s \bar{\varphi} \bar{\delta} \times 50 = 300 P_s \bar{\varphi} \leq 50 \quad (16)$$

that is, $P_s \bar{\varphi} = 1/6$.

Fires usually breaks out in a room on a floor. Let's imagine a fire occurred in a building for

sleeping use having an unprotected single stairway. It may be reasonable to assume that the stairway will be involved in the hazard of the fire at the same time. Accordingly,

$$P_s \approx P_c \approx 2 \quad (17)$$

Using this value in Eqn.(14) yields

$$\bar{\varphi} = \frac{1/2}{P_s} = \frac{1/2}{P_c} = \frac{1}{4} \quad (18)$$

The efficiencies of the rescue by fire brigade φ should be independent of building use, so the same value as Eqn.(18) is invoked to Eqn.(15) to yield the relative stairway obstruction probability for non sleeping use as

$$P_s = \frac{1/6}{\bar{\varphi}} = \frac{2}{3}$$

Therefore, in summary

$$P_s = \begin{cases} 2 & \text{(for sleeping use)} \\ 2/3 & \text{(for non-sleeping use)} \end{cases} \quad (19)$$

Compared with Eqn.(12) for corridor, the difference between sleeping and non-sleeping uses is small. The interpretation may be such that a fire on a different floor is perceived by the occupants of the other floor less easily than a fire on the same floor even when the occupants are awake.

6. CONCLUSION

The criterion which may be used as an alternative to the existing provisions on common path length and the conditions allowed for a building having only one stairway is proposed. The criterion is summarized as follows:

$$\left\{ \sum_{k=1}^n \left\{ \sum_{i=1}^{k-1} Q(i) \bar{\varphi} \right\} \bar{P}(k) \right\} \bar{\delta} \leq Q_{ref} \quad (20)$$

and the values of the associated parameters are

$$\bar{\varphi} = \begin{cases} 1 & \text{(for no possibility of rescue)} \\ 1/4 & \text{(for possibility of rescue by fire brigade)} \end{cases}, \quad \bar{\delta} = 1,$$

$$\bar{P}(k) = \begin{cases} 2 & \text{(for sleeping use)} \\ 1/2 & \text{(for sleeping use and sprinklered)} \\ 1/3 & \text{(corridors, for non-sleeping use)} \\ 2/3 & \text{(stairways, for non-sleeping use)} \end{cases}, \quad Q_{ref} = 50$$

However, further consideration is needed for $\bar{\delta}$ for the various degree of stairway protection.

The average level of evacuation safety will be basically the same between the proposed standard and the existing provisions. However, the advantage of the proposed standard is that it is able to

take into account more factors affecting the safety of unidirectional escape within a logical context. This method will allow much more flexibility in building plans without deteriorating the current level of safety.

NOMENCLATURE

E	Expected number of occupants unable to escape
$p1$	Probability of fire occurrence in the room
$p2$	Probability that the fire develops to be a hazardous fire
$p3$	probability that the door is left open in fire
P	Exit obstruction probability
P^*	Reference exit obstruction probability
\overline{P}	Relative exit obstruction probability reference to P^*
P_c	Relative escape route obstruction probability of corridor
P_s	Relative escape route obstruction probability of stairway
Q	Number of occupant of a room or in a floor
φ	Efficiencies of the rescue by fire brigade
δ	Degree of protection of escape route

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Discussion

Brian Meacham: It seems to me in both this presentation and the past one, that you looked at finding a way to determining an equivalent level of safety to the existing codes. Did you put any effort into determining whether or not the current level of safety is really what you want to have in the new approach?

Ichiro Hagiwara: These two papers are consistent with the current level of safety provided by existing codes. However, in the various countries the codes vary. For example, in some countries, if there are sprinklers, then the length of the common path can be half. So those things could be taken into consideration as probabilities if the evacuation routes are blocked. And that's the purpose of this study. With this study, we will be able to discuss the various different types of codes in various countries on a common ground. I think that is the advantage of the formula. When we consider the performance-based fire design, it is necessary for us to establish standards for requirements for the purpose of compliance.

Howard Emmons: I'm a bit confused over one item, your capital "P" symbols are defined in your notations as probabilities. Probabilities must be between zero and one. Yet, your probabilities seem to be able to be two. What am I missing?

Ichiro Hagiwara: Well, yes, the "P" has to be between zero and one. In order to get the expected value, we should be able to know the absolute probability, but sometimes it is difficult to this. For example, under the existing code, if there are more than 50 occupants in the room, there should be more than two exits. However, it is not known how much of a risk is involved in this particular situation, in terms of absolute probability. The reason we have such regulations under the existing code is because that they consider there is a risk of the occurrence of such dangerous events as the probability of fifty multiplied by a certain probability value. So, in relation to the existing codes, this "P" refers to relative probability. If the probability of risk is twice as much, then "P" becomes two.

King-Mon Tu: I noticed in equation 10 you have $P(\text{bar})$ equals P divided by P^* . I would like to know if you could give me some example of how in equation 1, you have $P=(P_1)(P_2)(P_3)$. Can you give me an example?

Ichiro Hagiwara: This is something I explained in the previous paper. P_1 is the probability of fire occurrence in the room, P_2 is the probability of fire expanding, and P_3 is the probability of the fire expanding to the other area of the building, that is, fire or smoke extending to other parts of the building because the door is open, that probability. P^* means the probability of fire occurrence when an evacuation route is determined into one direction. And given that situation, $P(\text{bar})$ means the relative degree of danger.